Impact of Model Numerics on Weather Depiction 1.2

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Objective

- Given access to meteorological data, interpret numerical weather prediction products IAW an evaluation checklist. Meas: PC/W

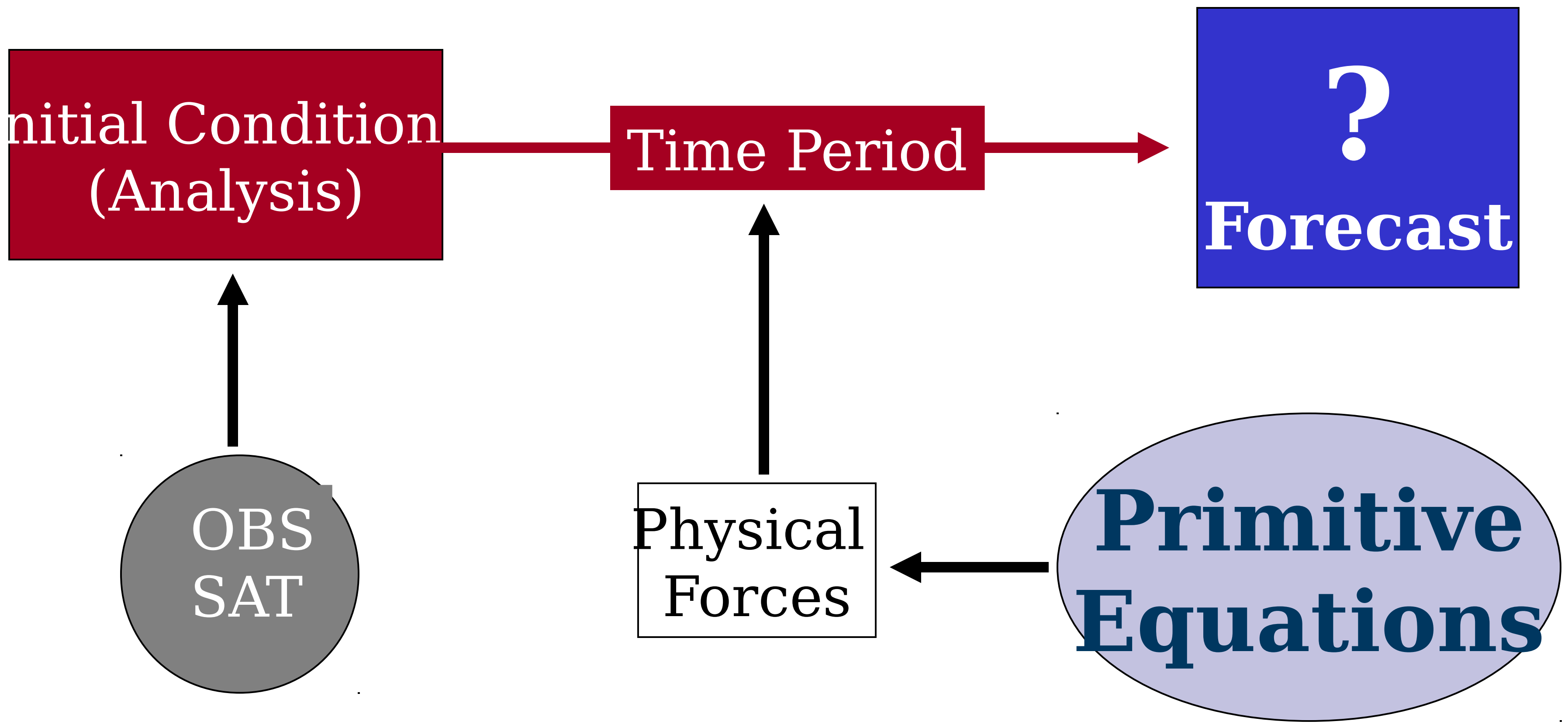
Topics Overview

1. Model Type
   - Grid point and Spectral
2. Vertical Coordinates
3. Horizontal Coordinates
4. Vertical Resolution
5. Domain & Boundary Conditions

Model Type Overview

1. Numerical Weather Prediction
2. The Primitive Equations
3. Approximations of Weather Features
4. How Models Solve the Forecast Equations
   - Grid point and Spectral
5. Hydrostatic/Non-Hydrostatic Models

Numerical Weather Prediction



Primitive Equations (PE): The Magic Five

- Wind Forecast Equations
- Continuity Equation
- Temperature Forecast Equation
- Moisture Forecast Equation
- Hydrostatic Equation

Primitive Equation Ultimate Aim!

- Understand,
  - All the primitive equations input and output data between the other formulas
  - If one equation has a problem it might skew another formula’s solution
  - Knowing this concept helps make assessments easier

Approximations of Weather Features

- Why Approximate?
  - Forecast equations cannot contain all details
    - Some features are too small
    - Current model resolution are too low
  - Therefore, atmospheric fields will be missing or misrepresented
- NWPs estimate the existence of events by solving other elements of an equations.

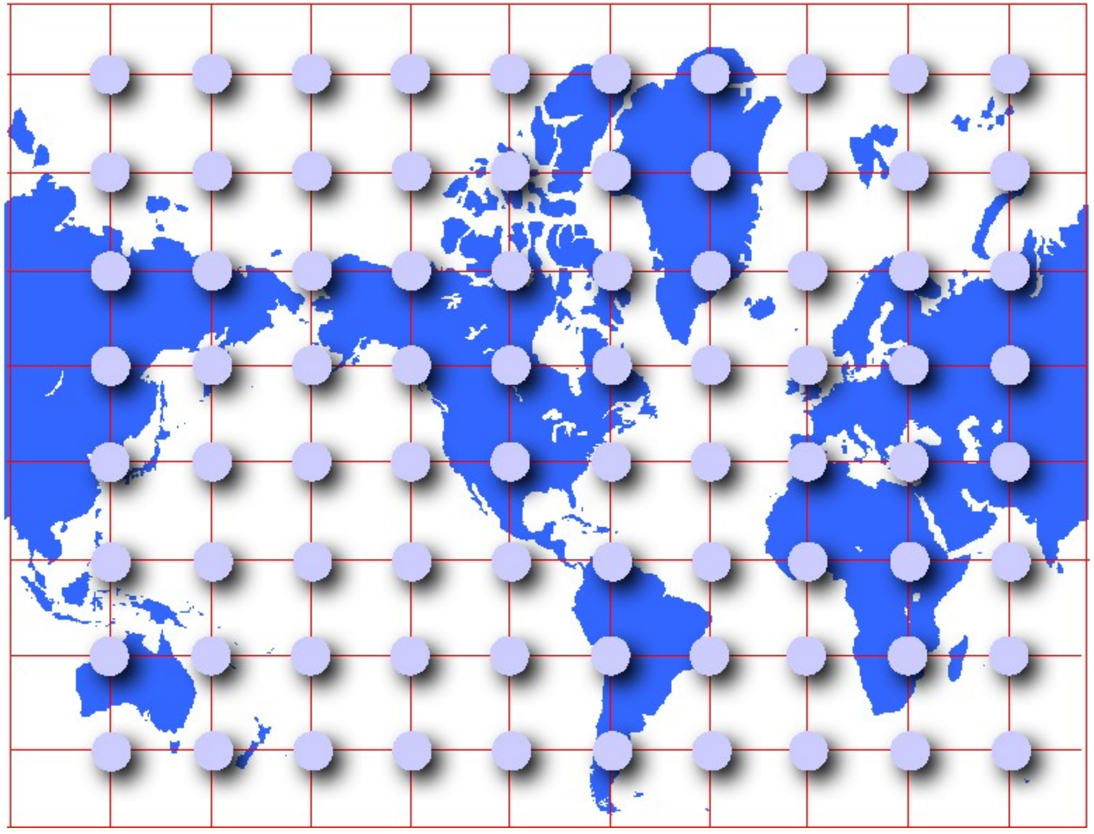
How Models Solve the Forecast Equations

Numerical models solve the forecast equations using one of two basic model formulations:

1. Grid Point
2. Spectral

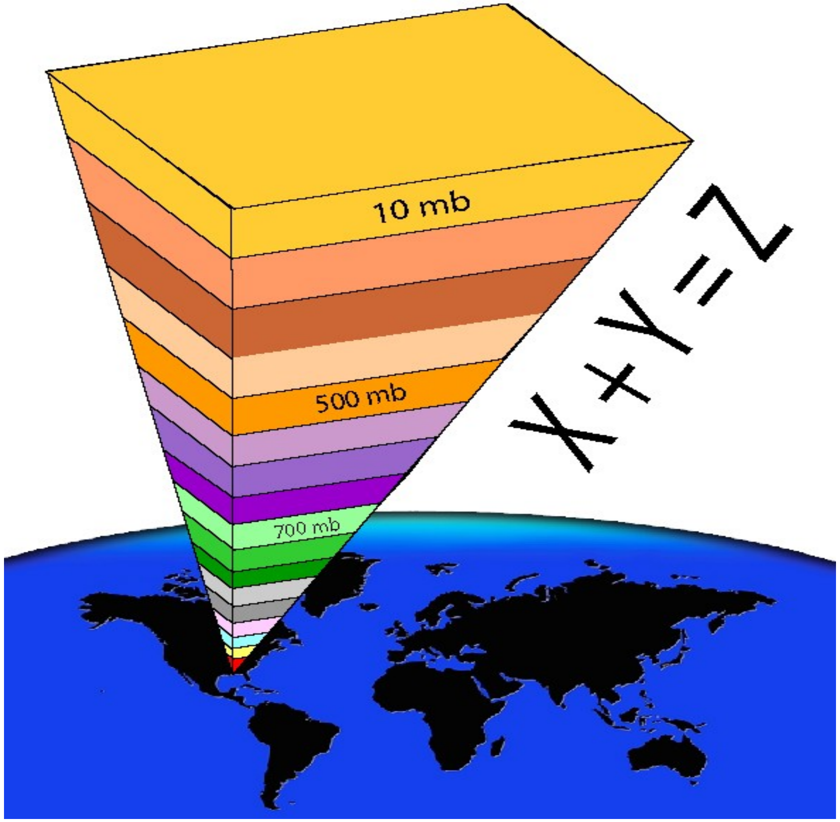
Grid Point Models

The forecast variables are specified on a set of evenly spaced grid points.



Grid Point Models

- Equations must be computed at all vertical levels for every point
- All forecast times must repeat the computation process

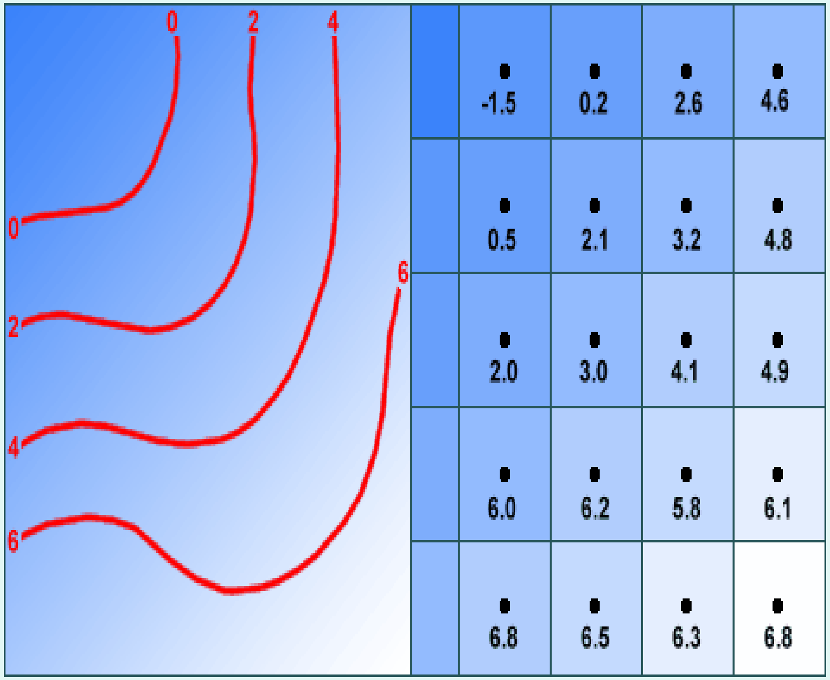


Spectral Models

- Use continuous waves to solve forecast equations
- Smooth waveform of a constant field
- Similar to hand-analysis of upper level height charts

Grid Point: Data Representation

- In the real atmosphere, weather features change in a smooth, continuous way
- Grid points are an average of the grid box, not exact values.



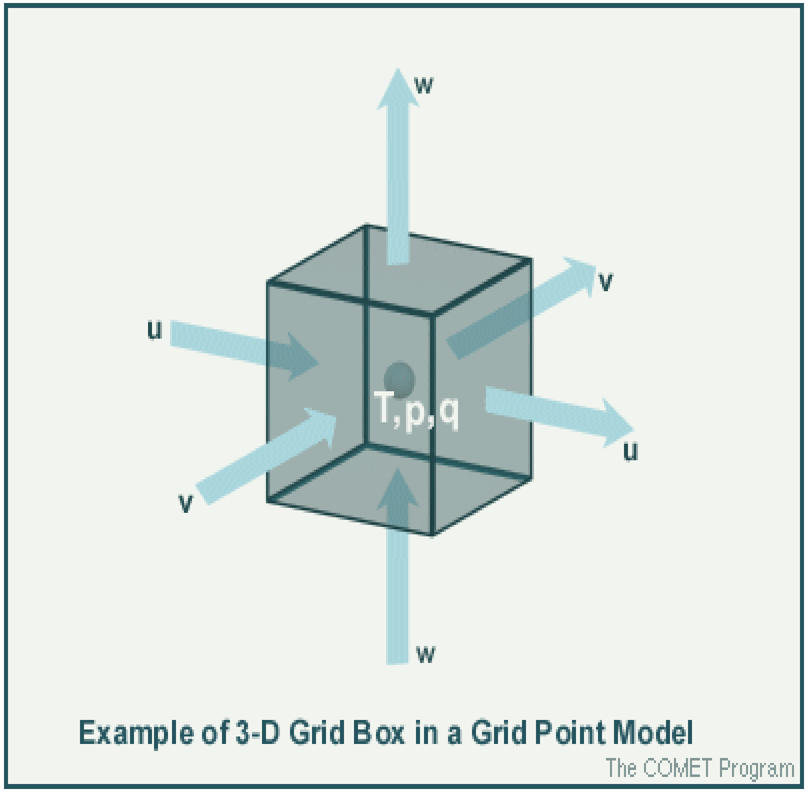
Actual smooth and continuous temperature field in degrees C (similar to spectral model representation)

Grid point model representation of the same temperature field in degrees C

The COMET Program

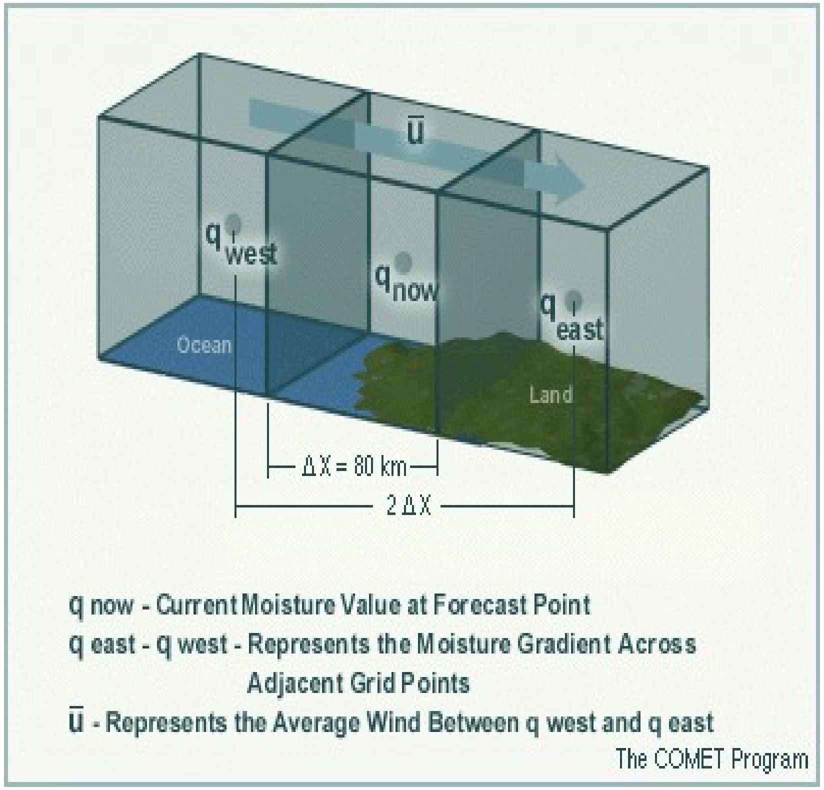
Grid Point 3-D Cubes

- Grid point models actually represent the atmosphere in three-dimensional grid cubes



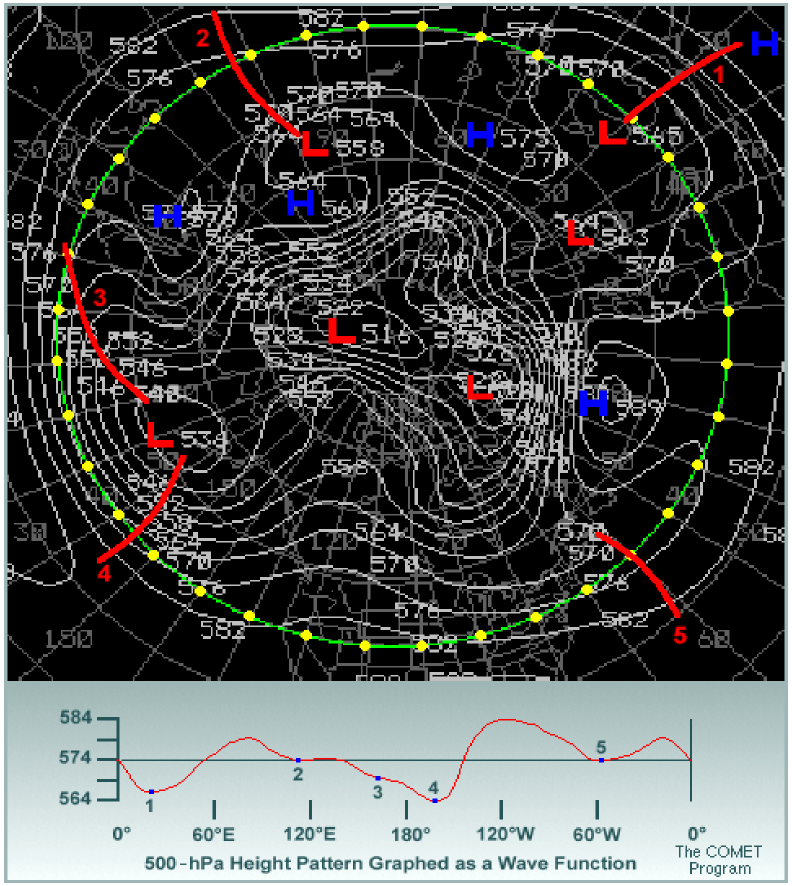
Grid Point: Truncation Errors

- Some weather features are very small scale
  - Sea Breeze
  - Temperature Variations
- Model grid point spacing is a factor in its accuracy
- Any lack of resolution introduces errors into the solution



Spectral Models: How Data are Represented

- Use continuous waves to solve forecast equations
- Smooth waveform of a constant field
- Similar to hand-analysis of upper level height charts

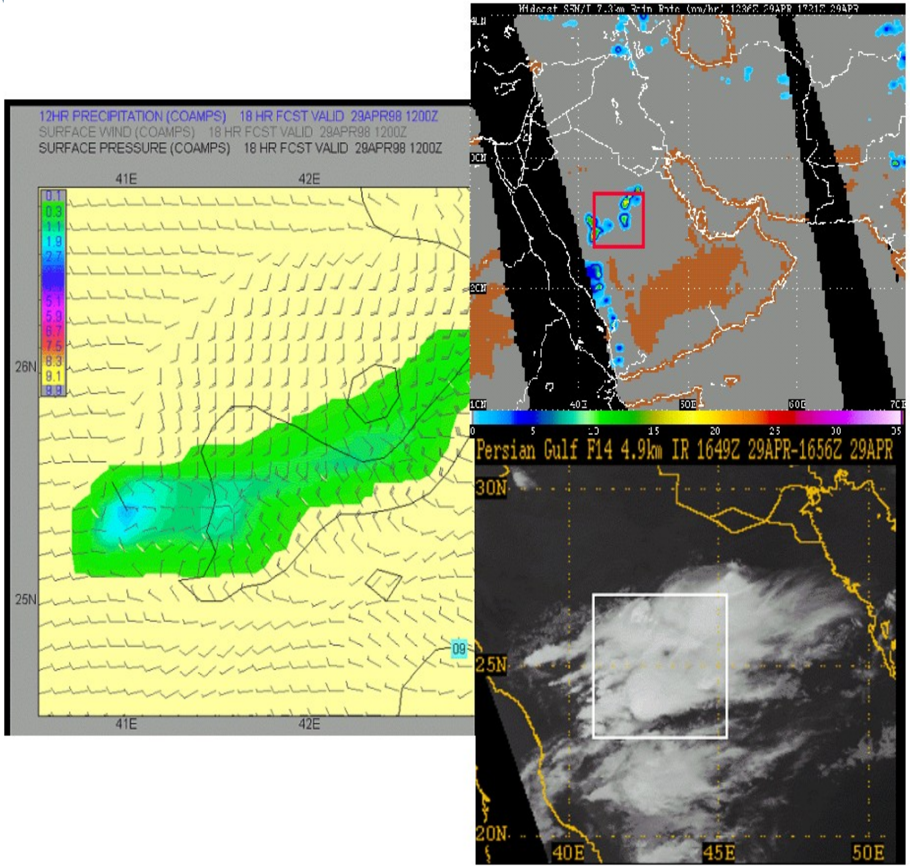


Hydrostatic/Non-Hydrostatic Models

- Hydrostatic – no vertical accelerations are calculated
  - Can not forecast for large scale thunderstorms
  - NOGAPS, MRF, and ECMWF
- Non-Hydrostatic – can calculate for convection
  - Can forecast for thunderstorms if grid size is small enough to depict the area.
  - COAMPS and AFWA's MM5

Example of a Grid Point, Non-Hydrostatic Model Forecast

- Mesoscale Convective Cell forecast by COAMPS Southwest Asia 9km nest
- 18 hour forecast showed gust front from maturing cells



Summary

1. **The concept for NWPs**
   - Initial conditions + forces that affect change = forecast
2. **There are Five Primitive Equations**
   - Wind, Continuity, Temperature, Moisture, Hydrostatic
3. **Approximations of Weather Features**
   - Forecast equations cannot contain all details at all resolutions
4. **Grid Point and Spectral models**
   - Two different techniques for computing the equations

Grid Point Model Summary

1. Data are represented on a fixed set of grid points
2. Resolution is a function of the grid point spacing
3. All calculations are performed at grid points
4. Approximations are used for solving the equations
   - Error is introduced through approximations

Spectral Summary

1. Data are represented by wave functions
2. Originally designed for global domains
3. Generally not designed for higher resolution regional and mesoscale applications
4. Require less computing resources

Non-Hydrostatic Summary

1. Used for forecasting small-scale phenomena
2. Capable of predicting convection and mountain waves
3. Account for cloud and precipitation processes and their contribution to vertical motions
4. Take longer to run than hydrostatic models with the same resolution and domain size

Review Question #1

- What characteristics of the model forecast equations limit the accuracy of the forecast? (Select all choices that apply)

  1. They have approximations in the physics terms.
  2. Approximations are used in deriving the forecast equations.
  3. They cannot be solved accurately in either spectral or grid point models at any resolution
  4. The equations contain complex terms for which initial values cannot be determined accurately.

Review Question #2

- The use of either grid point or spectral methods in NWP models makes it possible to…

(Select all choices that correctly complete the following sentence)

1. Solve the model equations without producing errors.
2. Produce mathematical representation of the full atmosphere.
3. Completely represent all details of the atmosphere.
4. Derive and solve the model equations using a mathematical framework.

Review Question #3

- Both grid point and spectral methods have errors as a result of having to ________ equation values.

1. Ignore
2. Estimate
3. Specify
4. Intensify

Review Question #4

- Both methods leave out information, but in different ways. Spectral methods provide nearly perfect representation but are limited by the __________ of the phenomena.

1. Grid Spacing
2. Strength
3. Wave Length
4. Type

Review Question #5

- The errors in spectral methods are 'errors of omission,' whereas those in the grid point method are computational in nature. Both errors contribute to what is known as _______________.

1. Approximations
2. Wavelength effects
3. Finite errors
4. Truncation errors/effects

Review Question #6

(Fill in either Non-hydrostatic or hydrostatic)

1. __________ models can explicitly forecast vertical motion.
2. __________ models are used especially for forecasting smaller-scale phenomena, such as convection.
3. ___________ models are used in global and regional models.
4. __________ models are used only over small domains.

Review Question #7

- Spectral models use __________ in its equation values, while grid point models use ___________ to define meteorological fields.

1. Wave lengths, linear terms
2. Grid boxes, wave functions
3. Continuous wave, grid boxes

Review Question #8

Which model type is best for forecasting each phenomenon?

(Fill in either Spectral, Grid Point (Non-hydrostatic) or Grid Point (hydrostatic)

1. __________ Planetary wave pattern for the next 7 days.
2. __________ Development and evolution of a mesoscale convective system.
3. ___________ Outflow boundary propagation
4. ___________ 24-hr boundary layer wind forecast.

References

1. MetEd: Numerical Weather Prediction Unit 1 – *Model Fundamentals*
   http://meted.ucar.edu/nwp/pcu1/ic1/frameset.htm

2. Isentropic Meteorology
   http://soo.wilm.noaa.gov/isentropic/